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Naphthotriazole derivatives: Synthesis and fluorescence properties

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ABSTRACT

Eight fluorescent compounds containing a naphthotriazole moiety substituted at position 2 by a (vinylsulfonyl)aryl group or its precursors, containing either a hydroxyl or sulphonic acid groups or *N*-methylglycine, were prepared and characterized. The products were recovered in moderate yield after column chromatography or recrystallization and identified using ^{1}H and ^{13}C NMR; double resonance, heteronuclear multiple quantum coherence and heteronuclear multiple bond correlation experiments were carried out for complete assignment of proton and carbon signals. Absorption and emission spectra were obtained, in acetonitrile and fluorescence quantum yield determined. All compounds offer promise as fluorescent probes owing to their high fluorescence quantum yield.

1. Introduction

Compounds containing the 1,2,3-triazole unit have attracted attention as intermediates for the synthesis of several products such as dyes [1] or optical brighteners [2]. In particular, naphthotriazoles exhibit intense fluorescence in the near UV and visible regions and their high fluorescence quantum yield (>50%, [3]), is comparable to that of highly fluorescent compounds such as 1-aminonaphthalene or 9,10-diphenylanthracene, which have quantum yields of $q_F = 39\%$ and $q_F = 98\%$, respectively [4]. Thus, naphthotriazoles are used as whitening agents [5] and/or as fluorescent probes [3]; sulfonated derivatives of 2*H*-naphthotriazoles are well-known in the textile industry [6].

Compounds and dyes containing vinylsulfonyl groups or their precursors display a marked ability to react with nucleophiles, such as those present in cellulose [7,8], nylon [9] wool [10,11] and other biomolecules [12]. The present research group recently described Michael reactions of vinyl sulfone derivatives and Amberlyst-15 as catalyst [13]. In general, dyes which carry a vinylsulfone group are commonly produced commercially in a protected form (e.g. as 2-sulfatoethyl sulfones) so as to prolong storage life and are converted to the corresponding, reactive vinylsulfone derivative *in situ* in the dye bath. A water soluble secondary amine such as *N*-methyltaurine can be used to protect the vinylsulfone group [14]; *N*-methylglycine (sarcosine), an amino acid containing a secondary amino group, was also developed for this purpose [15], the mechanism of dyeing [16,17] involving the release of the reactive vinyl form from the sulfate derivative under appropriate pH conditions [15].

This paper concerns the syntheses of novel 1,2,3-triazole derivatives containing reactive vinyl groups as potential markers for biomolecules and an evaluation of their fluorescence properties.

2. Results and discussion

2.1. Synthesis

The compounds described contain a naphthotriazole moiety and various substituents at the 2 position of the triazole ring (Fig. 1), which was obtained in low overall yield by diazotization of an aniline derivative [18] and azo coupling of the diazonium salt with an aminonaphthalene derivative followed by oxidation with copper acetate in DMF or similar, polar solvent at high temperature (Scheme 1) [6].

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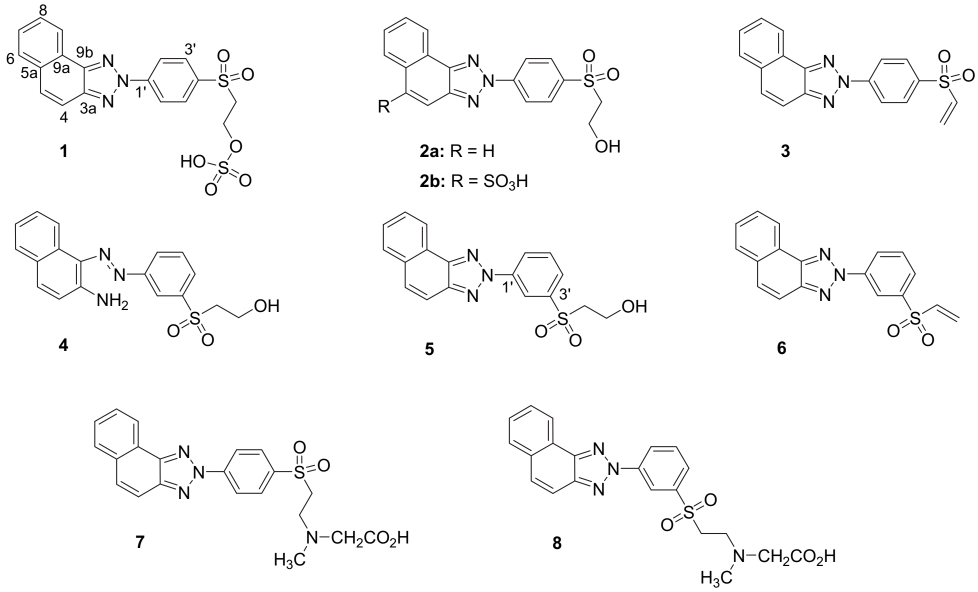


Fig. 1. Structures of compounds **1**–**8**.

During the preparation of compound **1** from 2-aminonaphthalene, a mixture of three compounds was obtained. Chromatographic purification of this mixture gave compound **1** (49%) and the alcohol **2a** (10%) which is explained by hydrolysis. In the ^{1}H-NMR of the crude mixture the characteristic pattern of the vinyl protons for compound **3**, formed by elimination, could be observed. This third compound, however, was not isolated by chromatography, as it was present in trace amounts only.

When the above impure mixture was treated with triethylamine and mesyl chloride [19] the vinyl compound **3**, was obtained in 20% yield; the same treatment of **2a** gave **3** in 22% yield. The formation of the vinyl sulfone was readily confirmed by ^{1}H NMR analysis which showed the expected splitting pattern for the vinyl protons.

Diazotization of 2-[(3-aminophenyl)sulfonyl]-1-ethanol and coupling (pH 7) with 2-aminonaphthalene, followed by heating with copper acetate in a mixture of pyridine and water, afforded the alcohol **5**, presumably through cyclisation of an intermediate such as **4**, that was not isolated. **2b** was prepared by the same method starting from 3-aminonaphthalene-1-sulfonic acid and 2-[(4-aminophenyl)sulfonyl]ethyl hydrogen sulfate in low overall yield (9%).

The procedure described above for the preparation of **3** was also used to prepare the vinyl compound **6** from the alcohol **5** in 33% yield.

Compound **7** was obtained using a sequence involving an ipso-coupling reaction [20] between the 4-[(2-sulphatoethyl)-sulfonyl] benzenediazonium sodium salt and 2-aminonaphthalene-1-sulfonic acid (displacement coupling with loss of the sulfonic acid group), followed by oxidation with copper acetate in a mixture of pyridine and water and finally reaction with sarcosine, perhaps via intermediate **9** (Scheme 2). Compound **8** was obtained (55% yield) by addition of sarcosine to vinyl derivative **6**.

The ^{1}H and ^{13}C NMR data for all the compounds confirmed the proposed structures (Tables 1 and 2).

2.2. Spectral data

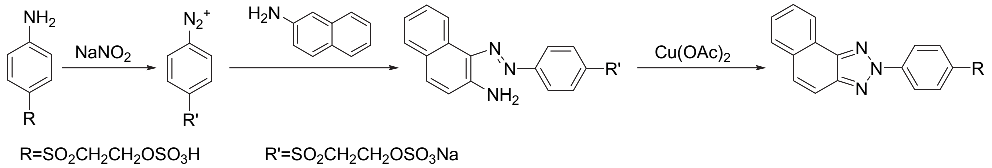
Acetonitrile (HPLC grade, Sigma–Aldrich Co.) was chosen as solvent for spectral measurements, taking into account the position of the bands in the absorption spectrum and the low solubility of the compounds under study in apolar solvents.

The shapes of the absorption and emission spectra for all the compounds are very similar to those of compound **3** (Fig. 2). The first absorption band of the triazoles consists of two vibronic bands; the long-wave absorption maxima are located at ~360 nm for the *p*-derivatives, and at ~355 nm for the *m*-derivatives.

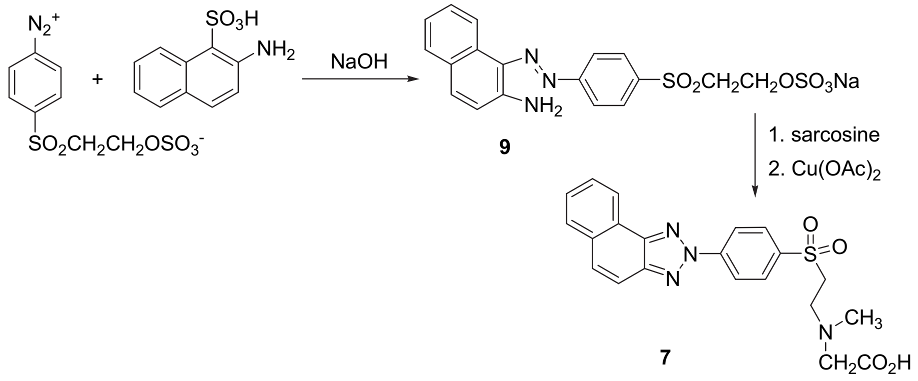
Regarding vibrational structure and high intensity of the first absorption band (absorption coefficient is about 17,000 L mol^{-1} cm$^-$1, see below), this band corresponds to S_0–$S_1(\pi,\pi^*)$ transitions. The intense sharp short-wavelength absorption band with maximum at ca. 290 nm (Fig. 2) probably corresponds to the local absorption of the substituted phenyl ring.

The slight hypsochromic shift observed for the absorption bands of *m*-derivatives compared with that of *p*-derivatives is probably due to an increase of the dihedral angle between the triazole and phenyl rings in the case of *m*-derivatives or/and to conjugative electronic effects.

The position and the shape of the fluorescence spectra (curve 2 in Fig. 2) were found to be independent of excitation wavelength both at 290 and 340 nm. The positions of fluorescence maxima are practically of the same value: ~380 nm for *p*-derivatives and ~360 nm for *m*-derivatives.



Scheme 1. Synthesis of compound **1**.



Scheme 2. Synthesis of compound **7**: 2-aminonaphthalene-1-sulfonic acid as secondary component (*ipso*-coupling).

The Stokes shifts of the studied compounds are very small, demonstrating a slight difference in geometry between vertical and relaxed (emitting) states, which may be related to the planarity of the triazole chromophore.

The fluorescence quantum yields (q_F) of triazoles were referenced to that of 1-aminonaphthalene as a fluorescence standard (1-aminonaphthalene has $q_F = 39\%$, [4]) because of the similarity between its absorption and fluorescence spectra with those of triazole derivatives.

It is evident that all the studied triazoles fluoresce with high q_F (Table 3). Nonetheless, there is a decrease of fluorescence quantum yield in the case of the sarcosine derivatives 7 and 8 to 62 and 54%, respectively.

3. Experimental

3.1. General

Melting points were determined on a Gallenkamp melting point apparatus and are uncorrected. ^1H NMR (300 MHz) and ^{13}C NMR (75.4 MHz) spectra were recorded on a Varian Unity Plus Spectrometer at 298 K or on a Bruker Avance III 400 spectrometer (400 MHz for ^1H and 100.6 MHz for ^{13}C). Chemical shifts are reported in ppm relative to solvent peak or TMS; coupling constants (*J*) are given in Hz. Double resonance, HMQC (heteronuclear multiple quantum coherence) and HMBC (heteronuclear multiple bond correlation) experiments were carried out for complete assignment of ^1H and ^{13}C signals in the NMR spectra. IR spectra were recorded on a Perkin Elmer FTIR 1600. High-resolution mass spectra (EI) were obtained on an AutoSpec E spectrometer and ESI mass spectrum on a LC–MS Finnigan LXQ spectrometer. UV/vis spectral data were measured in acetonitrile (HPLC grade, Sigma–Aldrich Co.) solutions in 1-cm quartz cuvette. Absorption spectra were recorded using a Perkin–Elmer Lambda 35 spectrophotometer. Fluorescence emission spectra were recorded using a Perkin–Elmer LS 55 spectrophotometer; excitation wavelength was 340 nm. Excitation at 340 nm was selected because it corresponds to the absorption maximum of the second vibronic band of $S_0 \rightarrow S_1$ transition and does not overlap with the fluorescence spectrum. Fluorescence emission spectra were corrected for characteristics of the emission monochromator and the photomultiplayer response. Fluorescence quantum yields q_F of triazoles were referred to 1-aminonaphthalene as fluorescence standard ($q_F = 39\%$ [4]). TLC was carried out on plates coated with silica gel 60 F_{254}. Column chromatography was performed on silica gel (230–400 mesh) with light petroleum-ethyl acetate mixtures of increasing polarity, unless other conditions are described. Light petroleum refers to the fraction boiling in the range 40–60 °C.

Table 1
^1H NMR chemical shifts (ppm, in DMSO-d_6 except otherwise indicated).

	Compound/chemical shift							
	1	**2a**[a]	**2b**	**3**[b]	**5**	**6**[b]	**7**	**8**
H4	7.91	7.89	8.29	7.73	7.80–8.00	7.71–7.80	7.89–7.93	7.93
H5	7.94	7.95	–	7.77	7.80–8.00	7.71–7.80	7.89–7.93	7.93
H6	8.55	8.63–8.70	8.95	7.87	8.00–8.15	7.86–7.98	8.50–8.53	8.58
H7 and H8	7.71–7.80	7.74–7.85	7.70–7.79	7.56–7.74	7.60–7.80	7.60–7.75	7.72–7.75	7.70–7.80
H9	8.08	8.07–8.12	8.54–8.59	8.55	8.57	8.58–8.68	8.06–8.08	8.64
H2′	8.16	8.25	8.16	8.05	8.74	8.92	8.18–8.22	8.77
H3′	8.54	8.66	8.54–8.59	8.54	–	–	8.50–8.53	–
H4′	–	–	–	–	8.63	8.58–8.68		8.04–8.11
H5′	8.54	8.66	8.54–8.59	8.54	7.80–8.00	7.71–7.80	8.50–8.53	7.93
H6′	8.16	8.25	8.16	8.05	8.00–8.15	7.86–7.98	8.18–8.22	8.04–8.11
SO_2CH_2	3.55	3.58	3.55	–	3.61	–	4.11	3.67
CH_2O	3.75	3.96–4.08	3.73	–	3.76	–		
OH	–		4.92	–	no	–	no	no
$SO_2CH=$	–	–	–	6.71	–	6.78	–	–
$=C\underline{H}$, *trans* SO_2	–	–	–	6.10	–	6.16	–	–
$=C\underline{H}$, *cis* SO_2				6.50		6.60		
CH_2N							3.82	2.93
CH_3N							2.28	2.20
NCH_2CO_2							3.22	3.14

[a] Acetone-d_6.
[b] $CDCl_3$ no-not observed.

Table 2
^{13}C NMR chemical shifts (ppm, in DMSO-d_6 except otherwise stated).

	Compound/chemical shift							
	1	**2a**[a]	**2b**	**3**[b]	**5**	**6**[b]	**7**	**8**
C3a	143.66	144.30	139.64	144.17	143.34	143.96	144.29	143.39
C4	116.20	117.08	114.35	116.07	116.12	116.18	118.87	116.18
C5	130.94	131.71	146.78	130.79	130.64	130.55 or 130.58	136.31	130.65
C5a	132.23	133.60	128.99	132.46	132.11	132.48	137.58	132.16
C6	122.93	123.94	129.76	128.97	129.29	126.95 or 128.87	126.53	124.27
C7	128.27 or 128.50	128.91 or 129.19	127.95 or 127.97	127.77 or 128.09	128.16 or 128.31	127.78 or 127.98	128.34 or 128.50	128.17 or 128.31
C8								
C9	129.40	130.16	122.82	123.34	122.86	123.40	129.62	122.90
C9a	123.75	125.39	124.17	124.50	123.69	124.66	127.21	123.77
C9b	142.83	144.99	143.38	143.60	142.50	143.38	145.10	142.55
C1′	142.67	144.23	142.71	120.13	141.85	140.95	141.83	141.42
C2′	129.91	130.87	129.97	129.41	118.55	119.23	136.60	118.62
C3′	120.04	120.87	120.24	120.24	139.65	141.30	119.02	139.73
C4′	139.57	140.95	142.40	143.70	124.17	124.46	141.32	129.33
C5′	120.04	120.87	120.24	120.24	131.24	130.55 or 130.58	119.02	131.22
C6′	129.91	130.87	129.97	129.41	127.66	126.95 or 128.87	136.60	127.61
SO_2CH_2	57.76	59.20	57.84		57.61		51.31	52.49
CH_2O	55.08	56.74	55.13		55.01			
$SO_2CH=$				138.11		137.99		
$=CH_2$				128.30		128.98		
CH_2N							48.01	49.13
CH_3N							39.62	40.87
NCH_2							55.63	52.67
C=O							170.28	171.68

[a] Acetone-d_6.
[b] $CDCl_3$.

Extreme care must be taken in the use and disposal of 2-naphthylamine, as it is a proven mutagen and carcinogen that is harmful to health and the environment [21].

3.2. General procedures for the synthesis of compounds **1**, **2b**, **5** and **7**

3.2.1. Diazotization

To a solution of 2-[(4-aminophenyl)sulfonyl]ethyl hydrogen sulfate (5.7, 10 and 6 mmol for compounds **1**, **2b** and **7**, respectively) or 2-[(3-aminophenyl)sulfonyl]ethan-1-ol (6 mmol, for compound **5**, in H_2O (13.0 mL), was slowly added concentrated HCl (2.8 mL; 25 mmol). The reaction mixture was cooled to 0–5 °C and 5 M $NaNO_2$ (0.27 mL $mmol^{-1}$ of substrate) was added dropwise; the mixture was stirred for 30 min. Excess HNO_2 (I_2-starch test) was destroyed using amidosulfuric acid.

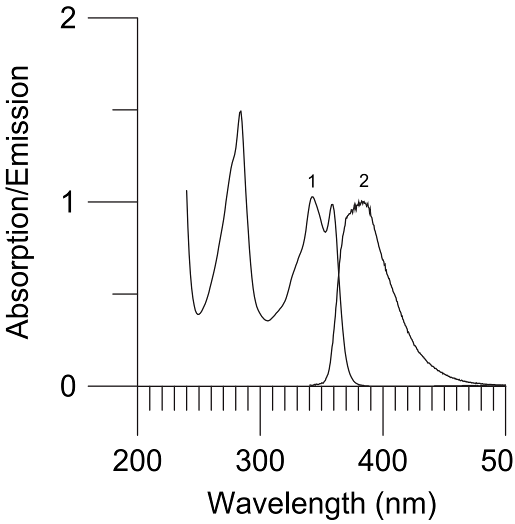


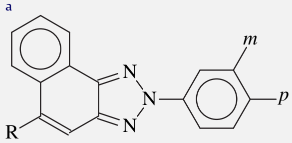
Fig. 2. UV/vis absorption (1) and fluorescence emission (2) spectra of compound **3** in CH_3CN at room temperature. Fluorescence spectrum was excited at 340 nm.

3.2.2. Azo coupling

To a solution of 2-aminonaphthalene (for compounds **1** and **5**) (7 mmol) in H_2O (10.0 mL), concentrated HCl (1.0 mL; 9 mmol) was added and the mixture heated for 10 min. After cooling, in an ice-acetone bath, the diazonium salt solution (Section 2.2.1) was added dropwise, the pH being adjusted to 5 using 5 M aq NaOH solution and the ensuing mixture was stirred for 1 h. When coupling was complete (H-acid test), the pH was adjusted to 7, the precipitated dye was filtered and used in the next step without drying.

In the case of **2b**, to a solution of 3-aminonaphthalene-1-sulfonic acid (2.23 g; 10 mmol) in H_2O (10 mL) was added 5 M aq NaOH (2.0 mL; 10 mmol). After cooling in an ice-acetone bath, the diazonium salt solution was added dropwise and the procedure described above was followed.

Table 3
Absorption maxima (A_{max}), fluorescence maxima (F_{max}) and fluorescence quantum yields (q_F) of derivatives of 2*H*-naphto[1,2-*d*][1,2,3]triazol-2-yl)benzene in acetonitrile.

Compound	[a] 	A_{max} (nm)	F_{max} (nm)[b]	q_F (%)
1	$-SO_2CH_2CH_2OSO_3H$ (*p*)	360	380	82
2b	$-SO_2CH_2CH_2OSO_3H$ (*p*), R=SO_3H	360	380	80
2a	$-SO_2CH_2CH_2OH$ (*p*)	360	375	83
5	$-SO_2CH_2CH_2OH$ (*m*)	353	362	81
3	$-SO_2CH=CH_2$ (*p*)	360	380	82
6	$-SO_2CH=CH_2$ (*m*)	354	363	81
7	$-SO_2CH_2CH_2N(CH_3)CH_2CO_2H$ (*p*)	360	380	62
8	$-SO_2CH_2CH_2N(CH_3)CH_2CO_2H$ (*m*)	354	362	54

[a] R=H, except otherwise indicated.
[b] Fluorescence spectra were excited at 340 nm.

3.2.3. *Oxidation with copper acetate*

To the above dye (obtained as described in Section 3.2.2), pyridine (5.0 mL), H_2O (2.0 mL) and $Cu(OAc)_2$ (2.5 g; 13.8 mmol) were added and the mixture was refluxed (15 min for compounds **1** and **2b**; 30 min for compound **5**) and then poured into water. The precipitated solid was filtered and dried; recrystallization from ethanol afforded the final compound.

3.3. *Synthesis and characterization of compounds **1–8***

3.3.1. *2-{[4-(2H-Naphtho[1,2-d][1,2,3]triazol-2-yl)-phenyl]sulfonyl}ethyl hydrogen sulfate (**1**)*

Yield: 1.2 g, 49%, m.p. 169–172 °C. UV $\lambda_{max}(\varepsilon)$: 284 ($2.55 \times 10^4$), 342 ($1.72 \times 10^4$), 358 ($1.66 \times 10^4$) nm. ^{1}H NMR (300 MHz, DMSO-d_6): $\delta = 3.55$ (t, $J = 6.0$ Hz, 2H, SO_2CH_2), 3.75 (t, $J = 6.3$ Hz, 2H, CH_2O), 7.71–7.80 (m, 2H (H-7, H-8), 7.91 (d, $J = 9.3$ Hz, 1H, H-4), 7.94 (d, $J = 9.0$ Hz, 1H, H-5), 8.08 (dd, $J = 2.1$, 6.6 Hz, 1H, H-9), 8.16 (d, $J = 9.0$ Hz, 2H, H-2′, H-6′), 8.54 (d, $J = 9.0$ Hz, 2H, H-3′, H-5′), 8.55 (dd, $J = 2.1$, 6.6 Hz, 1H, H-6)). ^{13}C NMR (75.4 MHz, DMSO-d_6): $\delta = 55.08$ (CH_2O), 57.76 (SO_2CH_2), 116.20 (C-4), 120.04 (C-3′, C-5′), 122.93 (C-6), 123.75 (C-9a), 128.27 and 128.50 (C-7, C-8), 129.40 (C-9), 129.91 (C-2′, C-6′), 130.94 (C-5), 132.23 (C-5a), 139.57 (C-4′), 142.67 (C-1′), 142.83 (C-9b), 143.66 (C-3a). HRMS calcd for $C_{18}H_{15}N_3S_2O_6$: 433.0402. Found: $(M - 1)^+$432.0313.

The mother liquor was extracted with ethyl acetate and the combined organic extracts were dried (anhydrous $MgSO_4$) and the oily residue obtained was subjected to column chromatography (EtOAc/light petroleum 5:1) yielding compound **2a** (0.2 g, 10%, m.p. 201–202 °C).

3.3.2. *2-{[4-(2H-Naphtho[1,2-d][1,2,3]triazol-2-yl)-phenyl]sulfonyl}ethan-1-ol (**2a**)*

UV $\lambda_{max}(\varepsilon)$: 284 ($2.60 \times 10^4$), 342 ($1.74 \times 10^4$), 358 ($1.70 \times 10^4$) nm. ^{1}H NMR (300 MHz, acetone-d_6): $\delta = 3.58$ (t, $J = 6.3$ Hz, 2H, SO_2CH_2), 3.96–4.08 (m, 3H, CH_2O and OH), 7.74–7.85 (m, 2H, H-7, H-8), 7.89 (d, $J = 9.3$ Hz, 1H, H-4), 7.95 (d, $J = 9.3$ Hz, 1H, H-5), 8.07–8.12 (m, 1H, H-9), 8.25 (d, $J = 9.0$ Hz, 2H, H-2′, H-6′), 8.66 (d, $J = 9.0$ Hz, 2H, H-3′, H-5′), 8.63–8.70 (m, 1H, H-6). ^{13}C NMR (75.4 MHz, acetone-d_6): $\delta = 56.74$ (CH_2OH), 59.20 (SO_2CH_2), 117.08 (C-4), 120.87 (C-3′, C-5′), 123.94 (C-6), 125.39 (C-9a), 128.91 and 129.19 (C-7, C-8), 130.16 (C-9), 130.87 (C-2′, C-6′), 131.71 (C-5), 133.60 (C-5a), 140.95 (C-4′), 144.23 (C-1′), 144.30 (C-3a), 144.99 (C-9b). HRMS calcd. for $C_{18}H_{16}N_3SO_3$: 354.0912 $(M + 1)^+$. Found: $(M + 1)^+$354.0913.

3.3.3. *2-{4-[(2-Hydroxyethyl)sulfonyl]phenyl}-2H-naphtho[1,2-d][1,2,3]triazole-5-sulfonic acid (**2b**)*

Yield: 0.39 g, 9%, m.p. 172–175 °C. UV $\lambda_{max}(\varepsilon)$: 283 ($2.50 \times 10^4$), 342 ($1.70 \times 10^4$), 358 ($1.64 \times 10^4$) nm. ^{1}H NMR (300 MHz, DMSO-d_6): δ = 3.55 (t, $J = 6.0$ Hz, 2H, SO_2CH_2), 3.73 (apparent q, $J = 6.0$ Hz, 2H, CH_2O), 4.92 (t, $J = 6.0$ Hz, 1H, OH), 7.70–7.79 (m, 2H, H-7, H-8), 8.29 (s, 1H H-4), 8.16 (d, $J = 9.0$ Hz, 2H, H-2′, H-6′), 8.54–8.59 (m, 3H, H-9, H-3′, H-5′), 8.95 (dd, $J = 7.2$, 2.0 Hz, 1H, H-6). ^{13}C NMR (75.4 MHz, DMSO-d_6): $\delta = 55.13$ (CH_2O), 57.84 (SO_2CH_2), 114.35 (C-4), 120.24 (C-3′, C-5′), 122.82 (C-9), 124.17 (C-9a), 127.95 and 127.97 (C-7, C-8), 128.99 (C-5a), 129.76 (C-6), 139.64 (C-3a), 129.97 (C-2′, C-6′), 142.40 (C-4′), 142.71 (C-1′), 143.38 (C-9b), 146.78 (C-5). HRMS calcd. for $C_{18}H_{15}N_3S_2O_6$: 433.0402. Found: $(M - 1)^+$432.0313.

3.3.4. *2-[4-(Vinylsulfonyl)phenyl]-2H-naphtho[1,2-d][1,2,3]triazole (**3**)*

To a dichloromethane (3.2 mL) solution of **2a** (0.32 g; 0.9 mmol) maintained at 0 °C, was added triethylamine (0.35 mL; 2.5 mmol) and mesyl chloride (0.1 mL; 1.3 mmol) and the resulting mixture was stirred for 10 min. The solution was washed with saturated ammonium chloride, dried (anhydrous $MgSO_4$) and concentrated under vacuum. The residue was purified by crystallization from chloroform/diethyl ether yielding the title compound as a light brown solid (0.068 g, 22%), m.p. 195–196 °C (dec). UV $\lambda_{max}(\varepsilon)$: 284 ($2.55 \times 10^4$), 342 ($1.72 \times 10^4$), 358 ($1.66 \times 10^4$) nm. ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 6.10$ (d, $J = 9.6$ Hz, 1H, .dbnd;CH, *trans* SO_2), 6.50 (d, $J = 16.5$ Hz, 1H, =CH, *cis* SO_2), 6.71 (dd, $J = 16.5$, 9.6 Hz, 1H, SO_2CH), 7.56–7.74 (m, 2H, H-7, H-8), 7.73 (d, $J = 9.0$ Hz, 1H, H-4), 7.77 (d, $J = 9.0$ Hz, 1H, H-5), 7.87 (dd, $J = 7.5$, 1.5 Hz, 1H, H-6), 8.05 (d, $J = 9.0$ Hz, 2H, H-2′, H-6′), 8.54 (d, $J = 9.0$ Hz, 2H, H-3′, H-5′), 8.55 (d, $J = 7.5$ Hz, H-9). ^{13}C NMR (75.4 MHz, $CDCl_3$): $\delta = 116.07$ (C-4), 120.13 (C-1′), 120.24 (C-3′, C-5′), 123.34 (C-9), 124.50 (C-9a), 127.77 and 128.09 (C-7, C-8), 128.30 (=CH_2), 128.97 (C-6), 129.41 (C-2′, C-6′), 130.79 (C-5), 138.11 (SO_2C=), 132.46 (C-5a), 143.60 (C-9b), 143.70 (C-4′), 144.17 (C-3a). HRMS calcd. for $C_{18}H_{13}N_3SO_2$: 335.0728. Found: $(M)^+$335.0725.

3.3.5. *2-{[3-(2H-Naphtho[1,2-d][1,2,3]triazol-2-yl)-phenyl]sulfonyl}ethan-1-ol (**5**)*

Yield: 0.86 g, 41%, m.p. 158–159 °C. UV $\lambda_{max}(\varepsilon)$: 282 ($2.52 \times 10^4$), 338 ($1.69 \times 10^4$), 355 ($1.63 \times 10^4$) nm. ^{1}H NMR (300 MHz, DMSO-d_6): $\delta = 3.61$ (t, $J = 6.0$ Hz, 2H, SO_2CH_2), 3.76 (t, $J = 6.0$ Hz, 2H, CH_2O), 7.60–7.80 (m, 2H, H-7, H-8), 7.80–8.00 (m, 3H, H-4, H-5, H-5′), 8.00–8.15 (m, 2H, H-6′, H-6), 8.57 (dd, $J = 7.5$, 1.2 Hz, 1H, H-9), 8.63 (dd, $J = 7.8$, 1.2 Hz, 1H, H-4′), 8.74 (t, $J = 1.2$ Hz, 1H, H-2′). OH not observed. ^{13}C NMR (75.4 MHz, DMSO-d_6): $\delta = 55.01$ (CH_2O), 57.61 (SO_2CH_2), 116.12 (C-4), 118.55 (C-2′), 122.86 (C-9), 123.69 (C-9a), 124.17 (C-4′) 127.66 (C-6′), 128.16 and 128.31 (C-7, C-8), 129.29 (C-6), 130.64 (C-5), 131.24 (C-5′), 132.11 (C-5a), 139.65 (C-3′), 141.85 (C-1′), 142.50 (C-9b), 143.34 (C-3a). HRMS calcd. for $C_{18}H_{15}N_3SO_3$: 353.0834. Found: $(M)^+$353.0845.

3.3.6. *2-[3-(Vinylsulfonyl)phenyl]-2H-naphtho-[1,2-d][1,2,3]triazole (**6**)*

To a dichloromethane (4.7 mL) solution of alcohol **5** (0.52 g; 1.47 mmol) maintained at 0 °C, triethylamine (0.51 mL, 3.7 mmol) and mesyl chloride (0.14 mL; 1.8 mmol) were added and the mixture was stirred for 10 min. The solution was washed with saturated ammonium chloride solution, dried (anhydrous $MgSO_4$) and then concentrated under vacuum. The oily residue was purified by flash column chromatography (chloroform: methanol, 10:1). The first fraction gave the title product as a light-brown solid (0.16 g, 33%), m.p. 167–168 °C. UV $\lambda_{max}(\varepsilon)$: 281 ($2.22 \times 10^4$), 339 ($1.39 \times 10^4$), 354 ($1.30 \times 10^4$) nm. ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 6.16$ (d, $J = 9.6$ Hz, 1H, =CH, *trans* SO_2), 6.60 (d, $J = 16.5$ Hz, 1H, =CH, *cis* SO_2), 6.78 (dd, $J = 16.5$, 9.6 Hz, 1H, SO_2CH), 7.60–7.75 (m, 2H, H-7, H-8), 7.71–7.80 (m, 3H, H-4, H-5, H-5′), 7.86–7.98 (m, 2H, H-6, H-6′), 8.58–8.68 (m, 2H, H-9, H-4′), 8.92 (t, $J = 1.8$ Hz, 1H, H-2′). ^{13}C NMR (75.4 MHz, $CDCl_3$): $\delta = 116.18$ (C-4), 119.23 (C-2′), 123.40 (C-9), 124.46 (C-4′), 124.66 (C-9a), 126.95 (C-6′or C-6), 127.78 and 127.98 (C-7, C-8), 128.87 (C-6′ or C-6), 128.98 (=CH_2), 130.55 and 130.58 (C-5, C-5′), 137.99 (SO_2CH), 132.48 (C-5a), 140.95 (C-1′), 141.30 (C-3′), 143.38 (C-9b), 143.96 (C-3a). HRMS calcd. for $C_{18}H_{14}N_3SO_2$: 336.0807. Found: $(M + 1)^+$336.0812.

3.3.7. *2-{[4-(2H-Naphtho[1,2-d][1,2,3]triazol-2-yl)-phenyl]sulfonyl}ethyl (methyl)carbamic acid (**7**)*

To a suspension of 2-aminonaphthalene-1-sulfonic acid (1.37 g; 6 mmol) in H_2O (10.0 mL), 5 M aq NaOH (1.2 mL) was added. The solution obtained was cooled to 0–5 °C, and the diazonium salt solution (Section 2.2.1) was added portion wise, keeping the temperature below 5 °C and at pH 8 by the addition of 5 M aq NaOH solution. The azo coupling was complete after˜2 h (H-acid test) and the pH of the reaction mixture was lowered to 4 using aq HCl solution. The azo dye formed was collected by filtration.

The moist dye was suspended in water (12 mL), sarcosine (0.71 g; 8 mmol) was added and the pH adjusted to 8 by the addition of 5 M aq NaOH solution. The mixture was heated at 60 °C for 2 h, cooled to 5 °C and the pH adjusted to 5 using aq HCl solution. The dye obtained was salted out by the addition of 3 g NaCl and collected by filtration.

The filter cake was dissolved in pyridine (5.0 mL) and water (5.0 mL). Cupric acetate (2.5 g; 13.8 mmol) was added with stirring and the mixture was heated at 60 °C for 4 h. After cooling it was poured into 100 mL cold water and the precipitate was collected and dried at 30 °C. The crude product **7** was obtained in 94% yield (2.40 g). A pure sample of **7** for spectroscopic analysis was obtained by repeated mixing with acidified water (pH 1) and filtration, which removed the remaining pyridine and copper salts; m.p. 180–181 °C. UV $\lambda_{max}(\varepsilon)$: 282 ($2.30 \times 10^4$), 338 ($1.40 \times 10^4$), 355 ($1.29 \times 10^4$) nm. ^{1}H NMR (300 MHz, DMSO-d_6): $\delta = 2.28$ (s, 3H, CH_3), 3.22 (s, 2H, CH_2CO_2H), 3.82 (t, $J = 6.0$ Hz, 2H, NCH_2), 4.11 (t, $J = 6.0$ Hz, 2H, SO_2CH_2), 7.72–7.75 (m, 2H, H-7, H-8), 7.89–7.93 (m, 2H, H-4, H-5), 8.06–8.08 (m, 1H, H-9), 8.18–8.22 (m, 2H, H-2′, H-6′), 8.50–8.53 (m, 3H, H-3′, H-5′, H-6), the OH was not observed. ^{13}C NMR (75.4 MHz, DMSO-d_6): $\delta = 39.62$ (CH_3), 48.01 (CH_2N), 51.31 (SO_2CH_2), 55.63 (CH_2CO_2H), 118.87 (C-4), 119.02 (C-3′, C-5′), 126.53 (C-6), 127.21 (C-9a), 128.34 and 128.50 (C-7, C-8), 129.62 (C-9), 136.31 (C-5), 136.60 (C-2′, C-6′), 137.58 (C-5a), 141.32 (C-4′), 141.83 (C-1′), 144.29 (C-3a), 145.10 (C-9b), 170.28 (C=O).

*3.3.8. 2-{[3-(2H-Naphtho[1,2-d][1,2,3]triazol-2-yl)-phenyl]sulfonyl}ethyl (methyl)carbamic acid (**8**)*

The pH of a solution of sarcosine (0.029 g; 0.33 mmol) in H_2O (3.0 mL) was adjusted to 8–9 by the addition of aq NaOH solution (0.014 g; 0.35 mmol) and was then added to a solution of 2-(3-(vinylsulfonyl)phenyl)-2*H*-naphtho[1,2-*d*][1,2,3]triazole, **6**, (0.111 g; 0.33 mmol) in acetone (3.0 mL). The reaction mixture was heated under reflux for 2 h. After cooling the mixture in an ice bath, the pH was adjusted to 7 by the addition of 1 M aq HCl solution. The solid precipitated was filtered and dried, affording the titled compound (0.077 g; 55%); m.p. 256–258 °C.

^{1}H NMR (400 MHz, DMSO-d_6): $\delta = 2.20$ (s, 3H, CH_3N), 2.93 (t, $J = 5.4$ Hz, 2H, CH_2N), 3.14 (s, 2H, CH_2CO_2H), 3.67 (t, $J = 5.4$ Hz, 2H, SO_2CH_2), 7.70–7.80 (2H, m, H-7, H-8), 7.93 (apparent t, $J = 8.4$ Hz, 3H, H-4, H-5, H-5′), 8.04–8.11 (2H, m, H-4′, H-6′), 8.58 (d, $J = 6.6$ Hz, 1H, H-6), 8.64 (d, $J = 6.6$ Hz, 1H, H-9), 8.77 (t, $J = 1.5$ Hz, 1H, H-2′), OH not observed. ^{13}C NMR (100.6 MHz, DMSO-d_6): 40.87 (CH_3N), 49.13 (CH_2N), 52.49 (SO_2CH_2), 52.67 (CH_2 CO_2H), 116.18 (C-4), 118.62 (C-2′), 122.90 (C-9), 123.77 (C-9a), 124.27 (C-6), 127.61 (C-6′), 128.17 and 128.31 (C-7, C-8), 129.33 (C-4′), 130.65 (C-5), 131.22 (C-5′), 132.16 (C-5a), 139.73 (C-3′), 141.42 (C-1′), 142.55 (C-9b), 143.39 (C-3a), 171.68 (C=O). MS, ESI$^+$: 425.33 ($(M+1)^+$, 3%); 379.25 [$(M+1)^+$–CO_2H, 100%].

4. Conclusions

A series of compounds derived from naphthotriazole and containing reactive vinyl groups were synthesised and characterized. Due to their reactivity towards nucleophiles and their high fluorescence quantum yields, these compounds are promising fluorescent markers.

All the derivatives showed maximum wavelength of absorption at 350–360 nm and maximum of fluorescence at 360–380 nm. Those compounds containing vinylsulfonyl, ethylsulfatosulfonyl and/or hydroxyethylsulfonyl groups exhibit strong fluorescence, but derivatives containing sarcosine showed lower fluorescence, although still significant (54 and 62%).

The successful reaction of vinylsulfonyl precursors with sarcosine suggests that they may also react with more complex biomolecules.

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